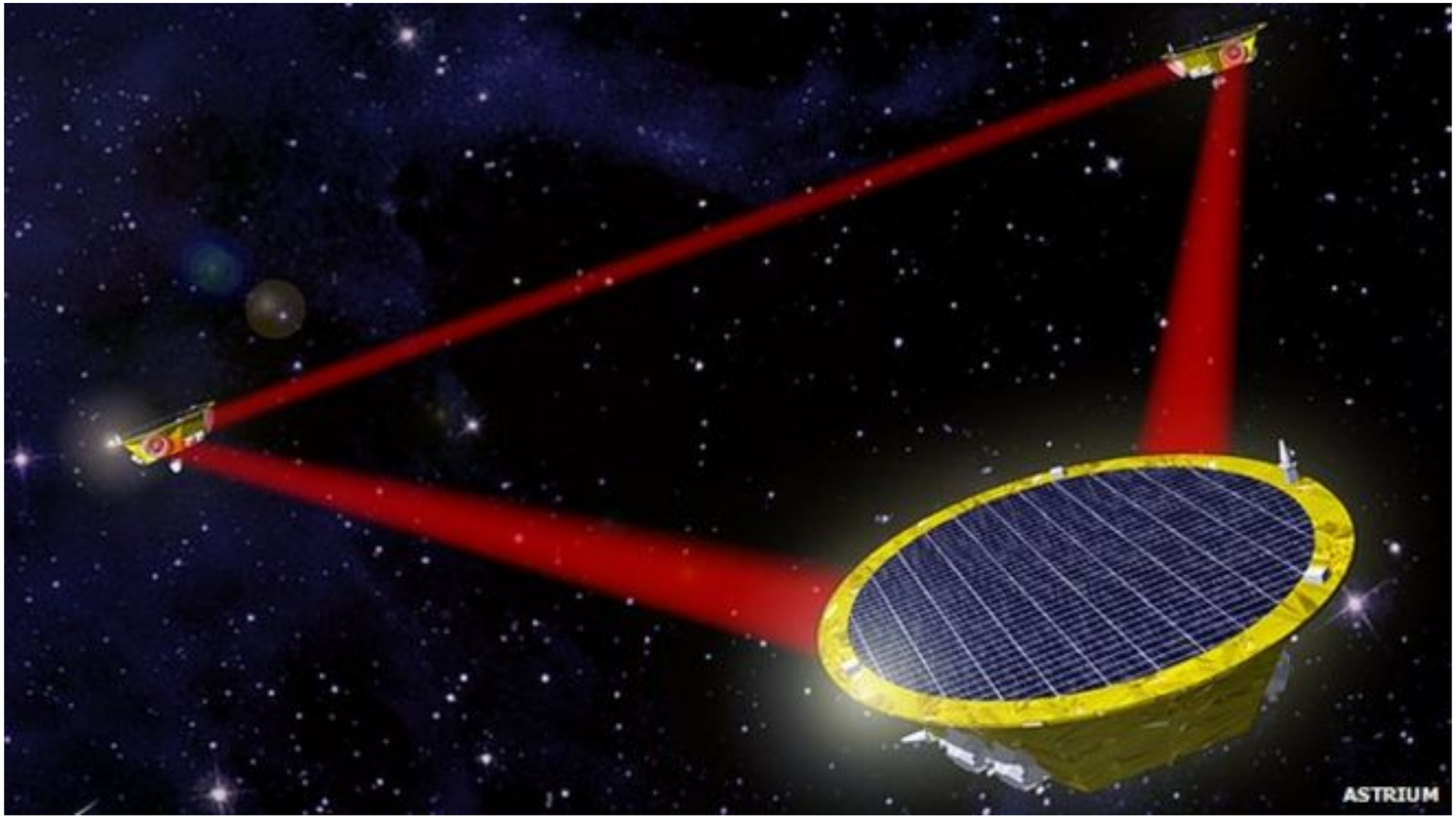
The ‘eyes’ of LISA

The Quadrant Photo-Receivers
A Dutch contribution to LISA

Niels van Bakel - October 1 2021 - LISA NL Day Leiden

Detecting Gravitational waves

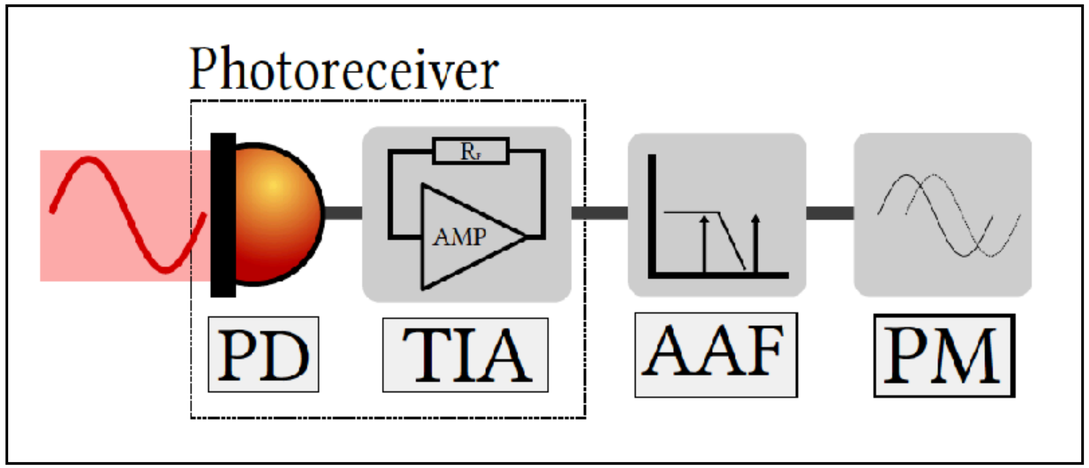
Requires sensitive photon detectors



- Laser power 1W
- Large distance gives divergence
- Receive only about 100 pW

The LISA Quadrant Photo-Receiver

LISA requires low capacitance diodes



- Large area diode
  - ➡ Simplifies the optical telescope
- Low input-referred current noise
  - ➡ < 2 pA/√Hz (per segment) ⟹ **Low capacitance**

$$I_{NEQ}(f) = \sqrt{V_{NA}^2\left(\frac{1}{R_{FB}^2} + 4\pi^2 f^2 (C_{PD} + C_{AMP})^2\right) + I_{NA}^2 + \left[4\pi f (C_{PD} + C_{AMP})\sqrt{k_B T R_{PD}}\right]^2 + \frac{4k_B T}{R_{FB}} + 2qI_{DARK}}\ ,$$

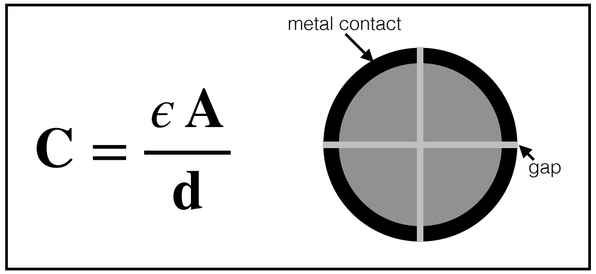
Opamp voltage noise | **Opamp current noise** | **Thermal PD series R** | **Thermal feedback R** | **Shot noise PD dark I**

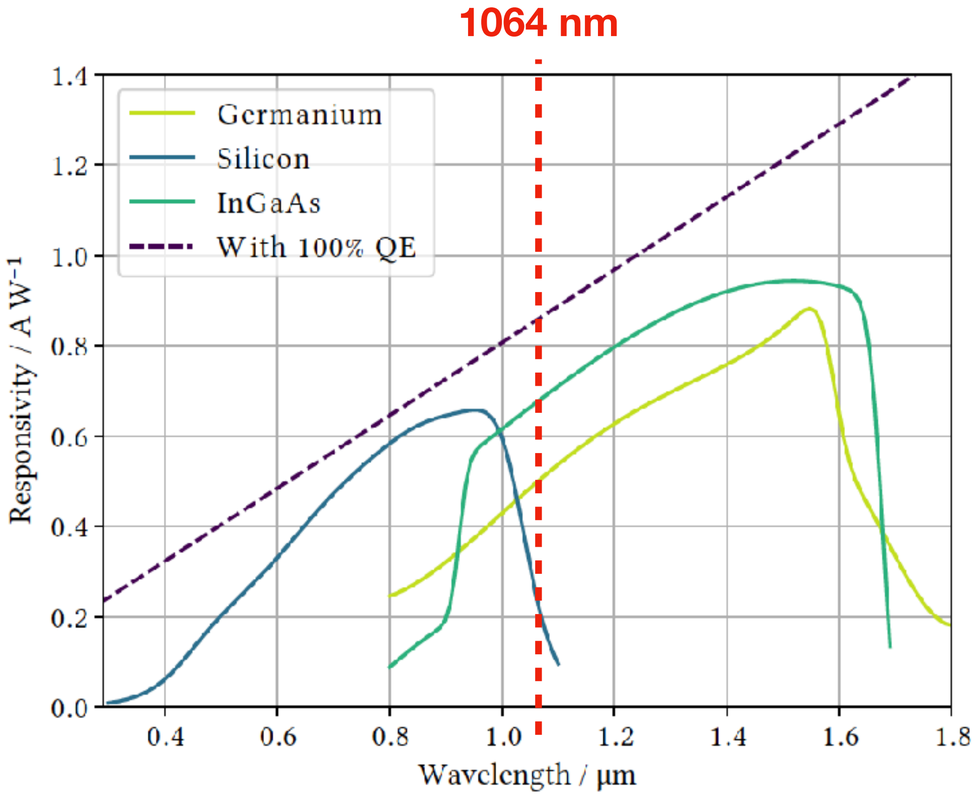
Eq (1) A. Joshi et. al 2012

Quadrant Photo-diodes

Not commercially available

- Large area
  - ➡ **2 mm diameter**, small gaps (10 - 20 µm) ⟹ High capacitance
- High responsivity
  - ➡ > 0.7 A/W at 1064 nm ⟹ **InGaAs**
- Commercially available InGaAs diodes
  - ➡ are thin ⟹ High capacitance

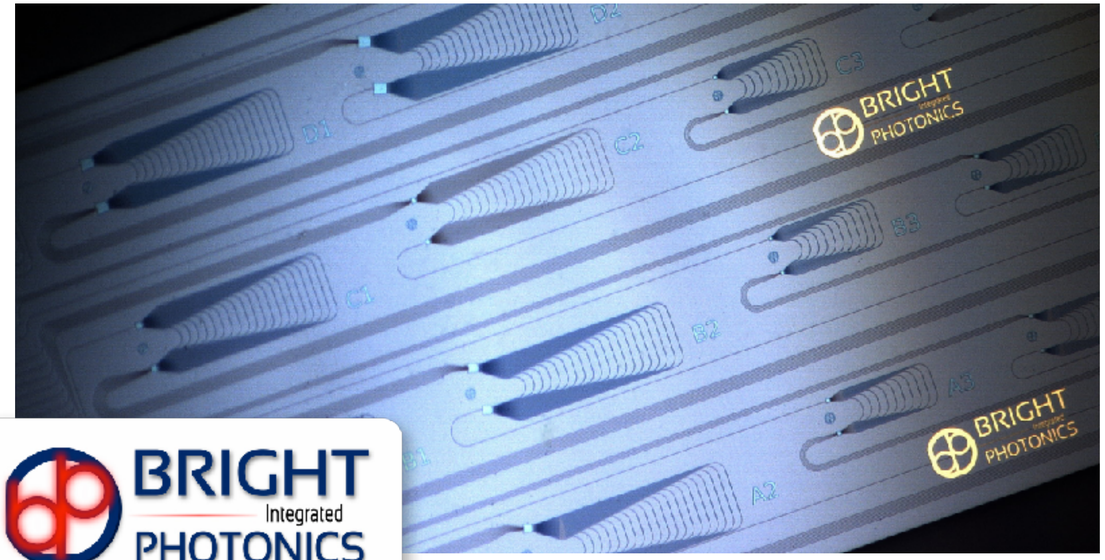




Laser wavelength fixed ⇒ 1064 nm

Dutch Photonics companies

They can help us!



BRIGHT Integrated PHOTONICS

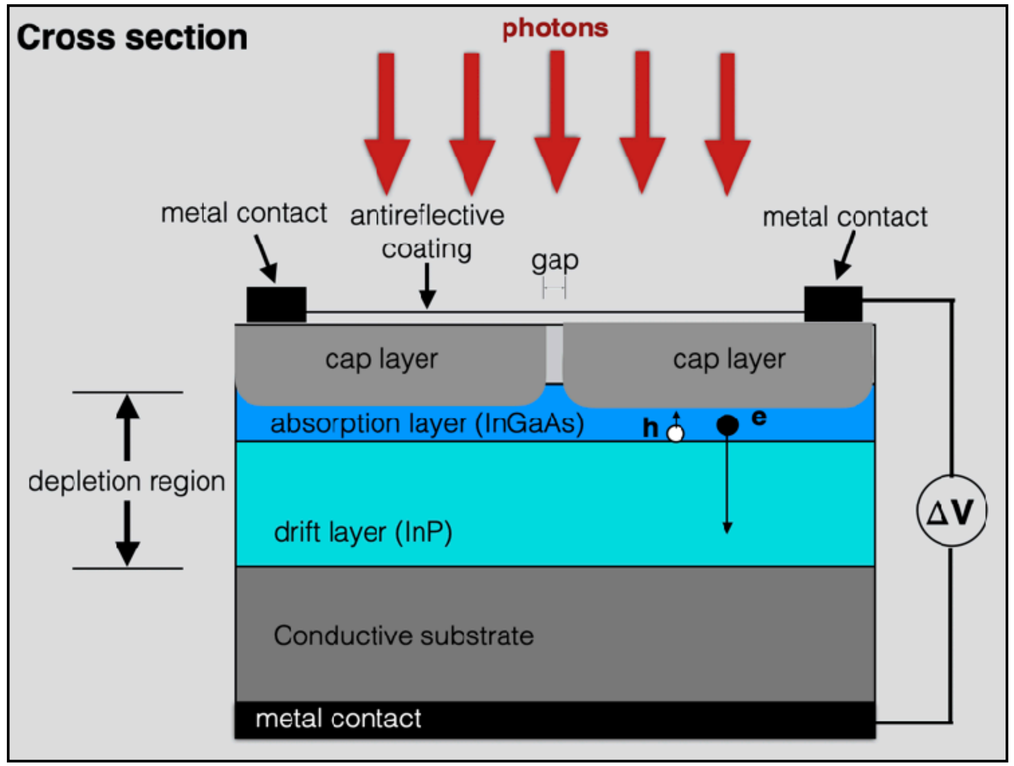
- ✓ *Design house for Photonic Integrated Circuits*
- ✓ *Experience with InP & InGaAs materials*

SMART PHOTONICS

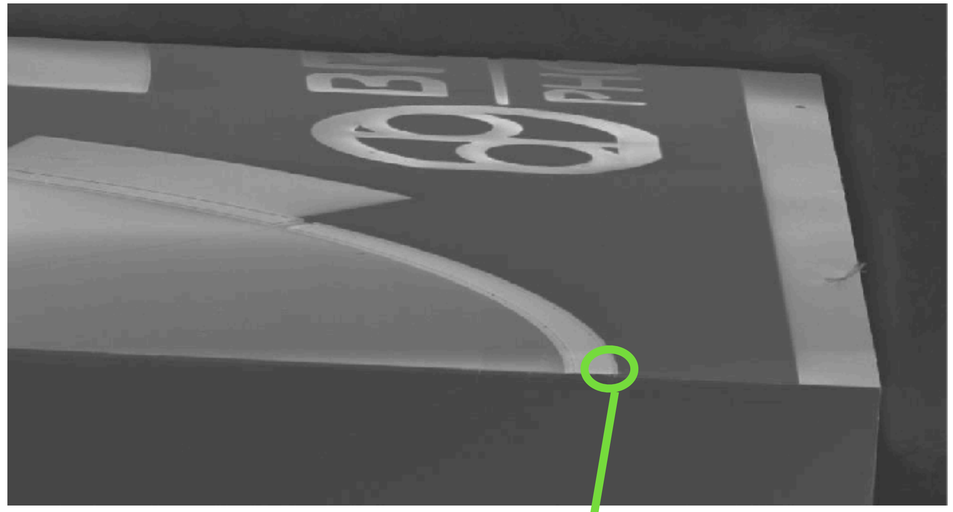
- ✓ *Device processing of Indium Phosphide based components*
- ✓ *Zn diffusion*
- ✓ *Anti-reflection coating*
- ✓ *Dicing*

Developing a customized QPD

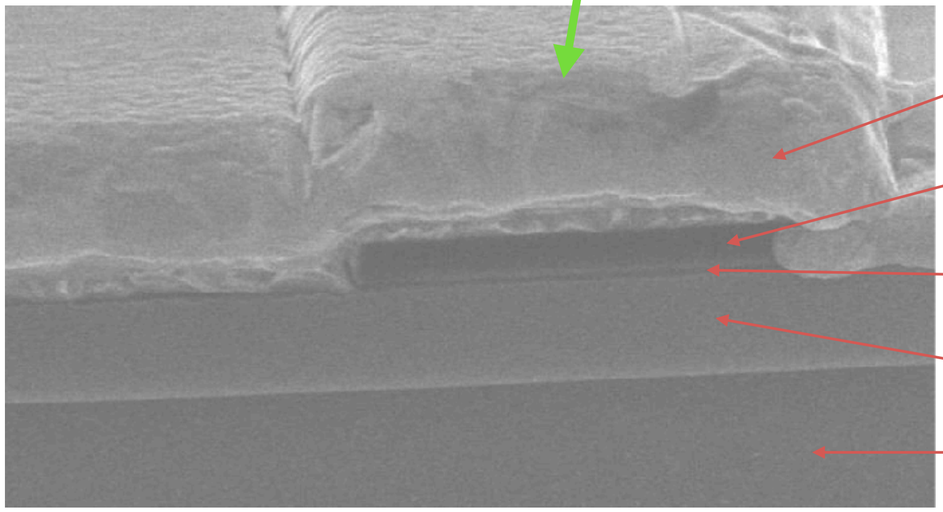
Optimizing the epitaxial layer-stack



- Bandwidth
  - ➡ 2..25 MHz

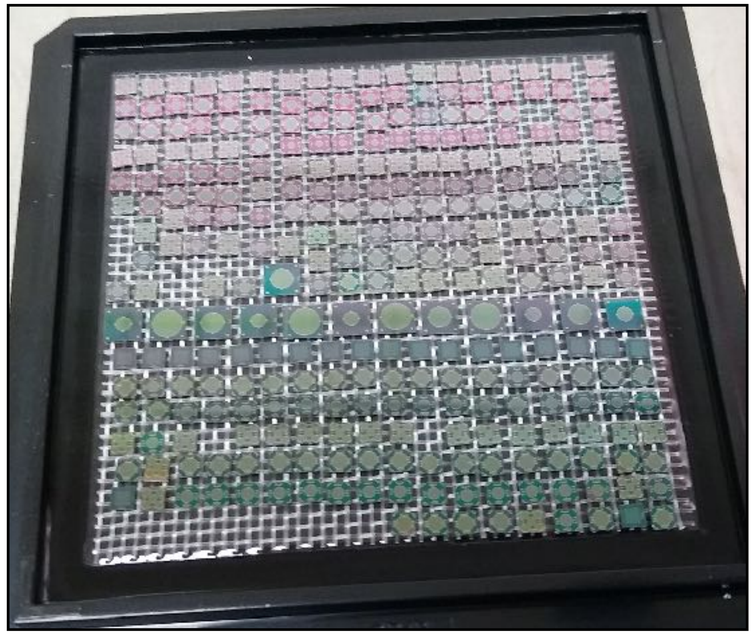


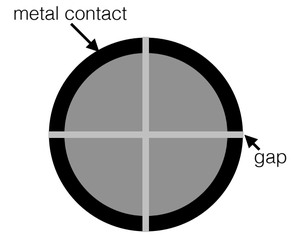
Images credit: Steven Kleijn (SMART Photonics)



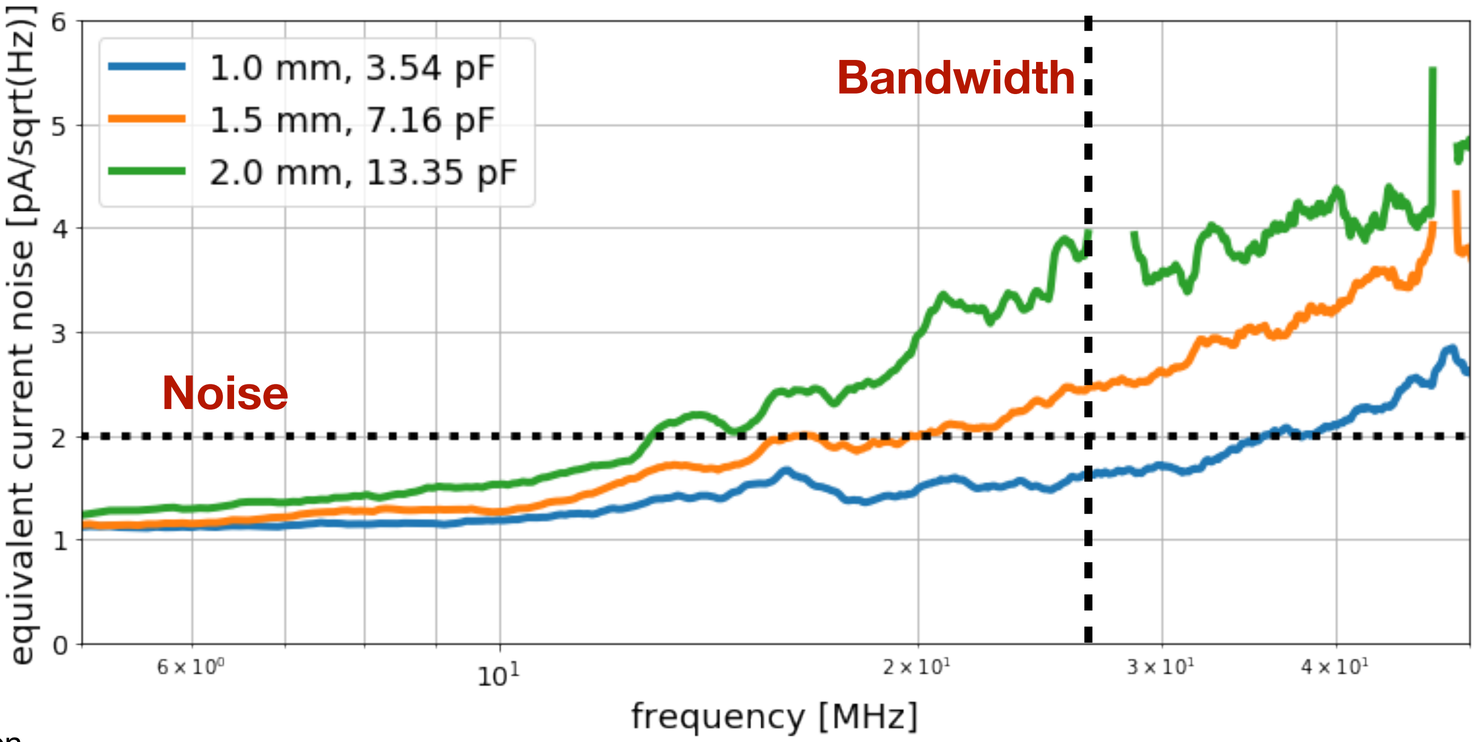
First QPD prototypes

Results are promising!



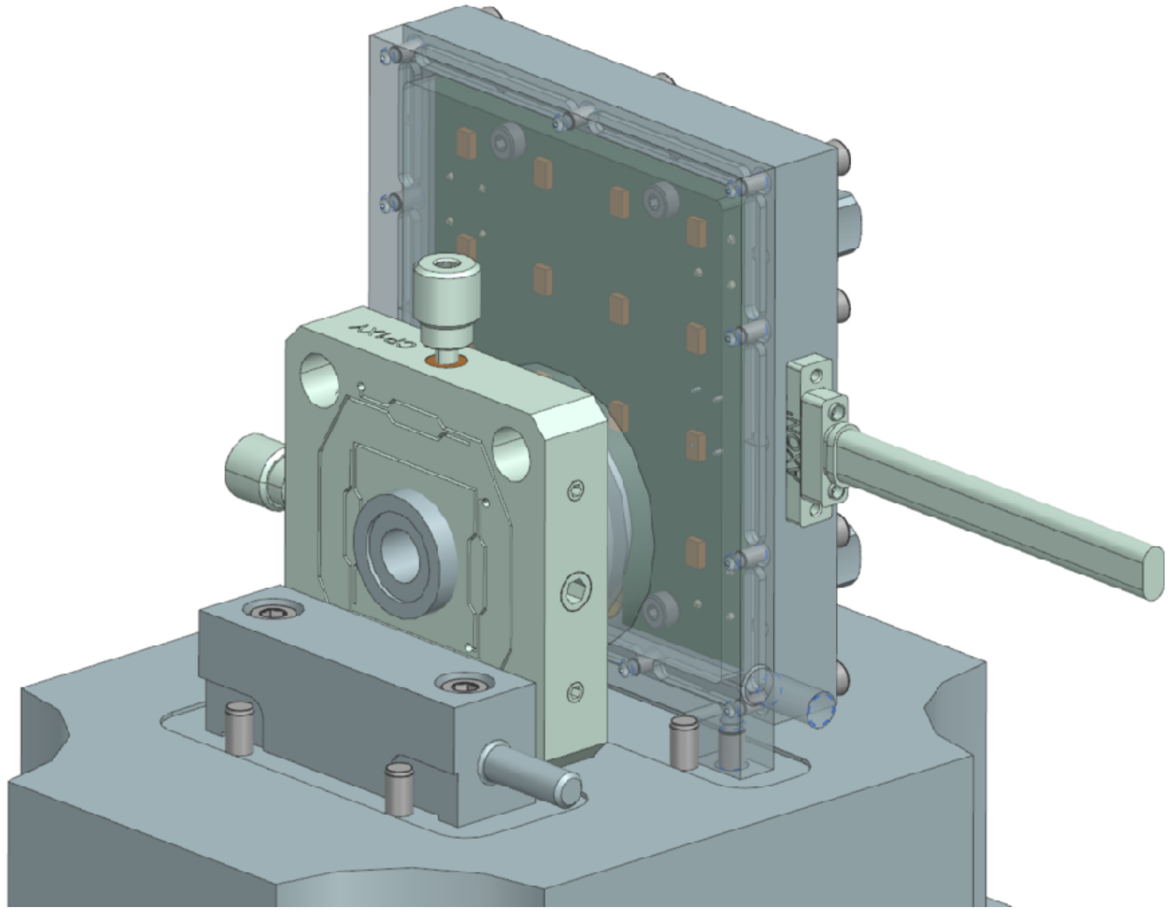


- Different layer stacks (4 types)
- Diodes with 15 layouts (gap size, diameter, single element)



Deliver to LISA

In total 72 QPR systems, first systems in 2027

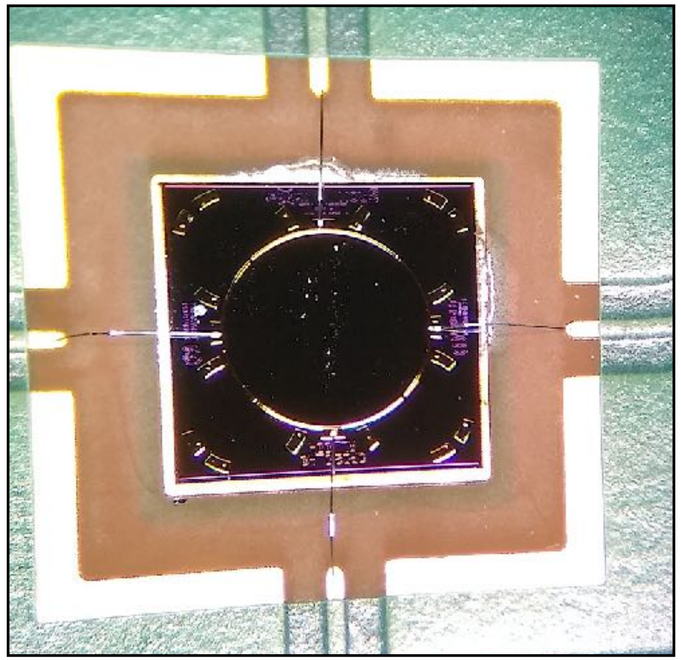


- Housing & mount
- EMC testing
- Cooling & Thermal stability
- Prepare diodes for radiation tests
- Readout ASIC (TIA) developed by KU Leuven
- Apply for funding
  - Consolidated budget for new QPD fabrication runs

Our ambitions

Areas where we could or want to play a role

- **LISA performance Working Group** (under LIG)
  - *NOT a simulator (does not produce data) but provides **noise budget***
  - *For **performance trade-offs** and to parametrize LISA performance*
  - *Missing: TDI physical modeling, **signal model at output of QPR** (only first attempt), **TTL** (can we use Ester's PAAM study), **DWS noise***
- **Interaction between (Dutch) LIG and LSG groups**
- **Get involved in phase meter tests & studies**
  - *EMC tests with modulated laser light*
  - *Phase meter modeling*
  - *……*



The Quadrant Photo-Receivers
A Dutch contribution to LISA - within the QPR-Working group

Nikhef

Niels van Bakel, Martin van Beuzekom, Daniela Pascucci (Postdoc), Guido Visser (EE), Kenny Lam (ME), Robin Cornelissen (ME)

SRON Netherlands Institute for Space Research

Jean in 't Zand, Frank Helmich, Jan Willem den Herder, Martin Frericks (SE), Phillip Laubert (Product Assurance), Rene Wanders (ME)

- **KU Leuven** - Front-end electronics design and development
- **JAXA** - QPR development and testing
- **AEI Hannover** - electronics, definition and testing of the Optical Metrology System, QPR expertise
- **ARTEMIS/OCA Nice** - stray-light studies, QPR characterisation before and after proton irradiation
- **UKATC Edinburgh** - QPR/OB interfaces
- **Airbus** - QPR/Instrument architecture